

OPTICAL FIBRE CONNECTOR

The present invention relates to optical fibre connectors for forming mechanical splices between optical fibres.

There are a wide variety of designs of optical fibre connector for forming mechanical splices (i.e. splices in which the fibres are spliced together by mechanical means). An example of one type of mechanical splice connector is disclosed in US Patent No. 4,946,249. The connectors disclosed in that document each comprise a pair of housing halves which, when assembled together provide a housing having a bore extending therethrough to accommodate the fibres being spliced. The fibres generally have coatings which need to be stripped away from the end sections of the fibres that are butted together to form the splice. The bore in the connector housing is wider at the ends of the housing to accommodate the coated sections of the fibres, and narrower in the middle of the housing to accommodate the bare stripped fibres. Because there is more than one typical thickness of an optical fibre coating, some of the connector housings have differing bore diameters at opposite ends of the housing, so that dissimilar sizes of fibre can be spliced together. There is also a respective connector housing for splicing together each size of optical fibre. Consequently a range of different connector housings is required.

US Patent No. 5,963,699 discloses optical fibre mechanical splice connectors comprising a base and a lid between which spliced optical fibres are clamped, by means of an external spring clamp that holds the base and the lid together. The lid is formed from three separate sections, i.e. a single middle section for clamping both stripped bare portions of the spliced fibres, and two end sections for clamping each of the two coated fibre portions. The spring clamp is divided into three section corresponding to the three sections of the lid, so that the clamping force can be adjusted for each lid section independently of the other sections.

The present invention provides optical fibre connectors that have major advantages over the known connector systems described above, including:

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- (i) "half-installability", i.e. the ability to install a first optical fibre (or a first set of optical fibres) in a mechanical splice connector, and to install a second optical fibre (or a second set of fibres) to be spliced with the first fibre(s) at a later time;
- (ii) the ability to close a "half-installed" mechanical splice connector such that the interior of the connector and the installed optical fibre(s) are protected, until the second optical fibre(s) is/are spliced;
- (iii) the ability to clamp the first optical fibre(s) against movement in the x, y, or z directions, and also against rotation, even while the second optical fibre(s) is/are spliced to the first fibre(s) – which enables the orientation of an angled cleaved end face of the (or each) first fibre to be fixed for subsequent splicing with a second fibre;
- (iv) the ability of a single mechanical splice connector to accommodate different diameters of optical fibre, for example both 250 μm diameter coated fibre and 900 μm diameter coated fibre; and
- (v) the versatility of a mechanical splice connector either not to include a means of precisely aligning the spliced optical fibres (where the numerical aperture of the fibres is such that no precise alignment is required), or to include any one of a variety of alignment means, to suit particular requirements.

Other advantages of the present invention will be apparent from the rest of this specification.

Accordingly, a first aspect of the present invention provides an optical fibre connector for forming a mechanical splice between first and second bare optical fibres stripped of coatings, the connector comprising a connector body that comprises at least two main clamping sections dimensioned to clamp directly onto the bare fibre of the first and second optical fibres, the main clamping sections arranged such that the first optical fibre may be clamped by a first of the main clamping sections independently of the second optical fibre, enabling the clamping of the first fibre against rotational and axial movement with respect to the connector body to remain substantially undisturbed by subsequent clamping or unclamping of the second fibre.

By "bare optical fibres stripped of coatings" is generally meant that end portions of the fibres to be spliced are stripped of coatings, or merely that the fibres (or at least their end portions)

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substantially lack coatings. The stripped coatings generally comprise primary coatings and/or buffer coatings.

As indicated above, the first aspect of the present invention provides a mechanical splice connector that enables a first optical fibre to be fixed in the connector, and a second optical fibre to be spliced with the first fibre at a subsequent time, without the first fibre being disturbed. This may be required, for example, so that the major parts of an optical fibre network may be deployed, and subscribers subsequently connected to the network as and when required. One example of why it may be important not to disturb the first fibre when the second fibre is spliced with it, is that the end face of the first fibre may have been cleaved at an angle with respect to the perpendicular (from its longitudinal axis) in order to prevent or at least minimize undesirable reflections back along the fibre from the end face (which may disrupt the transmission of data in the network). A great advantage of the present invention is that it can facilitate the mechanical splicing of a first fibre with a second fibre by maintaining the rotational orientation of an angled end face of the first fibre in the mechanical splice connector, and avoiding the need to disturb such orientation when the second fibre is introduced.

This first aspect of the invention enables the clamping of the first fibre to remain substantially undisturbed by subsequent clamping or unclamping of the second fibre because the main clamping sections (which are dimensioned to clamp directly onto both bare optical fibres) comprise at least two sections arranged such that the first fibre may be clamped by a first of the sections independently of the second fibre. The connectors disclosed in US Patent No. 5,963,699 do not have this advantage because the middle section of the lid of those connectors comprises only a single section dimensioned to clamp both of the bare fibres. Consequently, in order to clamp or unclamp a second fibre subsequently to the clamping of a first fibre, it would be necessary to unclamp the first fibre from the middle section of the lid of such a connector. Now, although the connectors disclosed in US 5,963,699 also include separate end sections that independently clamp the coated portions of the fibres (and which are not dimensioned to clamp directly onto the bare fibre stripped of coatings), the problem of the unclamping of the first fibre is still not solved, because it is a fact that an optical fibre clamped only by its outer coating (and not clamped directly onto the central bare fibre itself) is generally able to rotate about its axis. Consequently, the connectors disclosed in US

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5,963,699 are not generally able to preserve the rotational orientation of a first installed fibre when a second fibre is added to, or removed from, the connector.

As described below, the connectors according to the present invention may (and preferably do) include additional independent end clamping sections arranged to clamp the coated sections of the fibres. The two or more main clamping sections arranged to clamp the bare fibres categorically are not equivalent to such additional clamping sections of the present invention or of the prior art.

10 As indicated above, in addition to the two or more main clamping sections configured to clamp directly onto the bare fibre of the first and second stripped optical fibres, the connector body preferably includes at least one, and preferably at least two, additional clamping sections dimensioned/configured and arranged to clamp onto coated portions of the optical fibres, i.e. portions of the fibres from which the coatings have not been stripped.

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A second aspect of the invention provides an optical fibre connector for forming a mechanical splice between first and second optical fibres, the connector comprising a connector body that comprises at least four clamping sections configured to clamp the first and second optical fibres, the clamping sections arranged such that the first optical fibre may be clamped by at least one of the clamping sections independently of the second optical fibre, enabling the clamping of the first fibre against rotational and axial movement with respect to the connector body to remain substantially undisturbed by subsequent clamping or unclamping of the second fibre.

25 Preferably at least two of the clamping sections of the second aspect of the invention are the main clamping sections of the first aspect of the invention. At least one, but preferably at least two, of the clamping sections of the second aspect are the preferred additional clamping sections of the first aspect.

30 In particularly preferred embodiments of the invention, the connector comprises at least five clamping sections.

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The connector may include at least three main clamping sections configured to clamp directly onto bare optical fibre. A first of the main clamping sections may be arranged to clamp onto the first fibre only, a second of the main clamping sections may be arranged to clamp onto the second fibre only, and a third of the main clamping sections may be arranged to clamp onto both of the first and second fibres.

The connector body of the connector according to all aspects of the invention preferably includes at least one bore arranged to accommodate the optical fibres. Preferably, the main clamping sections and the bore of the connector body are configured to clamp the bare fibre of the first and second optical fibres in the bore. The (or each) bore preferably has a first region, and a second region of greater diameter than the first region at each end of the first region. More preferably, the bore has a third region of greater diameter than the second region at each end of the second region. Preferably at least the second and third regions of the bore are substantially circular in cross-section.

In preferred embodiments of the invention, the connector may include alignment means for aligning the first and second optical fibres with each other. Preferably the optical fibres are sufficiently aligned by the alignment means to form a splice that minimizes optical losses such that any losses are of an acceptable level. A preferred alignment means is a bore of the connector body, preferably a bore as referred to in the preceding paragraph. The bore preferably is dimensioned such that the stripped bare portions of the first and second optical fibres form a tight fit within the bore. The bore may comprise a groove of the connector body, for example a V-groove or a U-groove, and/or it may comprise a substantially circular cross-section bore. Additionally, or alternatively, the alignment means may comprise an alignment member in which the first and second optical fibres may be received and aligned. The alignment member may include an alignment bore for receiving and aligning the optical fibres. The alignment member may, for example, comprise a tube (or the like), for example a capillary tube. The tube may be formed from glass, for example. Alternatively, the alignment member may comprise at least one plate, preferably a pair of plates, each of which has an aperture for receiving a respective one of the first and second fibres. One or both plates may include a lens (e.g. a micro-lens) to assist in coupling light between the fibres. The plates may be the same as, or similar to, the Figure 13 embodiment of co-pending UK patent application number 0309908.2 filed on 30 April 2003.

A third aspect of the invention provides an optical fibre connector for forming a mechanical splice between first and second optical fibres, the connector comprising a connector body including a bore for accommodating the fibres, the bore having a first region, a second
5 region of greater diameter than the first region at each end of the first region, and a third region of greater diameter than the second region at each end of the second region opposite to that adjacent to the first region, wherein at least the second and/or third regions of the bore are substantially circular in cross-section.

10 As indicated above in the summary of US Patent No. 4,946,249 optical fibres come in a range of diameters depending on the size of the coating applied to the bare fibre. For example, two standard sizes of optical fibre are 250 μm diameter and 900 μm diameter. 250 μm fibre is generally known as primary coated fibre (due to its relatively thin outer coating), and 900 μm fibre is generally known as buffer coated fibre (due to its relatively thick outer
15 coating). The central fibre itself generally has a standard diameter irrespective of whether it is primary coated fibre or buffer coated fibre. A standard diameter for the bare fibre itself is 125 μm . Because optical fibres come in more than one size, it would be desirable to have a mechanical splice connector that could accommodate each size of fibre in one and the same device. This would avoid the need for a proliferation of different connectors for
20 accommodating the different fibre sizes and the combinations of differently sized fibres to be spliced, as exemplified by US Patent No. 4, 946,249. The third aspect of the present invention has the advantage of providing such a connector.

Preferably the first region of the bore of the connector is dimensioned to accommodate bare
25 optical fibre stripped of its coatings (e.g. the bare fibre having a diameter of approximately 125 μm), and each second region preferably is dimensioned to accommodate primary coated optical fibre (e.g. the primary coated fibre having a diameter of approximately 250 μm). Preferably each third region is dimensioned to accommodate buffer coated optical fibre (e.g. the buffer coated fibre having a diameter of approximately 900 μm). Consequently, one and
30 the same connector device may accommodate bare fibre, primary coated fibre, and/or buffer coated fibre. Preferably the second and third regions of the bore are dimensioned to accommodate coated optical fibres of different respective sizes. Consequently, by means of

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the second and third regions of the bore, the connector according to the invention fulfils the need for an optical fibre connector that can accommodate different sizes of optical fibre (due to the fibres having different thicknesses of coatings on the bare fibre) in one and the same connector device.

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In preferred embodiments of the invention, the connector body is divided into at least two parts along at least part of a length thereof, arranged such that the optical fibres may be clamped between the parts.

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Preferably the connector further comprises a resilient clamp member arranged to retain the optical fibres in a clamped condition in the connector body. Advantageously, the resilient clamp member may be arranged to be retained on the exterior of the connector body. The connector body may be arranged to retain the parts of the connector body together such that the optical fibres are clamped between the parts of the connector body.

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In some embodiments of the invention, the connector may include a plurality of ferrules or other fixing members, each of which is arranged to be fixed (e.g. crimped) to a respective optical fibre such that the ferrule or other fixing member is secured in the connector body when the fibres are spliced. Such ferrules or other fixing members may assist in retaining a desired rotational orientation of its respective fibre in the connector.

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The connector according to the invention may advantageously be arranged to form mechanical splices between a plurality of first and second optical fibres (e.g. multiple fibre splices). The connector body may therefore comprise a plurality of bores arranged to accommodate the plurality of first and second optical fibres.

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Some preferred embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, of which:

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Figure 1 illustrates the components of a preferred optical fibre connector according to the invention;

Figure 2 illustrates the connector of Figure 1 in an assembled state without optical fibres installed in the connector;

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Figure 3 illustrates the connector of Figures 1 and 2 in an assembled state with optical fibres installed and spliced in the connector;

Figure 4 illustrates a base part of the connector of Figures 1 to 3;

Figure 5 illustrates a lid part of the connector of Figures 1 to 4;

5 Figure 6 illustrates a resilient clamp member of the connector of Figures 1 to 5;

Figure 7 is a schematic diagram illustrating a method of opening the connector of Figures 1 to 6, enabling the insertion or removal of optical fibres into or from the connector;

Figure 8 illustrates a second preferred embodiment of an optical fibre connector according to the invention; and

10 Figure 9 is a schematic illustration showing three embodiments of alignment means of connectors according to the invention.

Figure 1 illustrates the components of a preferred optical fibre connector according to the invention. The connector 1 comprises a connector body comprising two parts 3 and 5 which
15 divide the connector body in two along the length of the connector body. The two parts 3 and 5 may be regarded as half-shells of the connector body. The first part 3 will be designated as a base part 3, and the second part 5 will be designated as a lid part 5. The base part 3 is shown in detail in Figure 4, and the lid part 5 is shown in detail in Figure 5. Each of the parts 3 and 5 includes a longitudinal channel which, when the parts are brought together
20 to close the connector body define a longitudinal bore 7 extending through the connector body. The bore 7 is for accommodating optical fibres 9 (refer to Figures 3 and 8) spliced in the connector in use.

The bore 7 comprises a longitudinally central first region 11, second regions 13 at each end
25 of the first region 11, and third regions 15 at each end of the second region 13 (opposite to the ends adjacent to the first region 11). Each second region 13 has a greater diameter than the first region 11, and each third region 15 has a greater diameter than its adjacent second region 13. As described earlier in the specification, the first region 11 of the bore 7 is dimensioned to accommodate bare optical fibre stripped of coatings in a tight clamping fit
30 when the lid part 5 and the base part 3 of the connector body are clamped tightly together. The bare optical fibre preferably has an external diameter of approximately 125µm.

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As shown in Figure 4, one of the parts of the connector body, preferably the base part 3, includes a semicircular cross-section channel as its portion of the first region 11 of the bore. The other part of the connector body, preferably the lid part 5 as shown in Figure 5 preferably is substantially flat in its first region, other than small recesses 17 which help to guide and retain the fibres in position. The fact that the first region of the bore is not circular in cross-section but includes a flat section helps to clamp the bare fibre tightly in the first region. The second and third regions, however, preferably are substantially circular in cross-section, as shown in Figures 4 and 5.

One or both of the second and third regions may include one or more retaining members arranged to cut into the respective coating of the optical fibre to provide axial pull resistance, especially in order to counter creep which might otherwise occur over time. Figures 1 and 4 show retaining members 19 in the third regions 15 of the bore 7 of the base part 3.

As shown in Figures 1 and 2, the connector may include plugs 21 arranged to close, and preferably to seal, the ends of the bore 7 prior to, and during, installation of the optical fibre splice. The plugs 21 preferably prevent dust or other dirt ingress into the connector, and preferably also water ingress into the connector, which could have a detrimental effect on the integrity of the splice. The plugs are removable from the bore to enable the optical fibres to be inserted.

As shown in Figures 1 and 5, at least one of the parts of the connector body, preferably the lid part 5, is divided into a plurality of sections 23 and 25. The sections 23 and 25 are clamping sections of the connector body. As illustrated, there are five clamping sections, comprising three main clamping sections 23 arranged to clamp directly onto the bare optical fibre in the first region 11 of the bore 7, and two additional clamping sections 25 arranged to clamp directly onto the coated portions of the optical fibres in the second or third regions of the bore 7.

Figure 5 illustrates how the clamping sections 23 and 25 are divided from each other along the length of the connector body. There is a continuous strip 27 of the connector body extending generally along one edge of the lid part 5, and each clamping section extends from the strip 27. Other than by contact via the strip 27, each clamping section is separated from

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each adjacent clamping section by a gap, thereby enabling the clamping sections to move, and therefore clamp, independently of each other.

As shown most clearly in Figures 1 and 6, the connector also includes a resilient clamp member 29 in the form of a generally U cross-section resilient metal member that is configured to be retained on the exterior of the connector body. The resilient clamp member 29 is arranged to retain the lid part 5 and the base part 3 together such that they are tightly clamped around the spliced optical fibres. The two generally parallel arms of the resilient clamp member are divided into clamping sections 31, which form part of the respective clamping sections 23 and 25 of the connector body. The clamping sections 31 of the resilient clamp member enable the clamping sections 23 and 25 of the connector to clamp the fibres independently of each other. A longitudinally central clamping section of the resilient clamp member 29 includes an aperture 33 arranged to receive a protrusion 35 on the connector body to retain the clamp member in place on the connector body.

Because the connector body and the resilient clamp member include three separate main clamping sections arranged to coincide with the first region 11 of the bore 7, the stripped bare portions of two optical fibres spliced in the connector may be clamped independently of each other. Specifically, a first main clamping section 23a clamps only a first bare optical fibre, a second main clamping section 23b which clamps both of the first and second bare optical fibres. Consequently, a tremendous advantage of the invention (as described earlier) is that a first optical fibre may be installed in the connector body in preparation for splicing with a second optical fibre to be installed in the connector body at a later time. The end face of the first optical fibre preferably is cleaved at a non-perpendicular angle with respect to the longitudinal axis of the fibre, in order to minimise back reflections. As a way of facilitating the splicing of the fibre to a second fibre (also having a non-perpendicular end face) it is preferably to determine and to retain the orientation of the end face of the first fibre in the connector body. The fact that the second fibre can be introduced into the connector body and spliced with the first fibre without requiring the unclamping of the first main clamping section 23a from the first fibre means that the orientation of the first fibre is retained.

The connector disclosed as US Patent No. 5,963,699 does not have the above advantage because the bare fibre sections of both fibres are clamped by one and the same central

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clamping section of that connector. The fact that there are separate clamping sections which separately clamp the coated portions of the fibres does not assist in retaining the fibre orientation, because the clamping to the coating (rather than the bare fibre) generally does not fix the orientation of a fibre against rotation.

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Figure 7 is a schematic cross-sectional diagram of the assembled connector showing how the lid and base parts 3 and 5 may be separated slightly to facilitate the insertion of the optical fibres to be spliced. The lid and base parts 3 and 5 together provide a recess 35 on the open side of the resilient clamp member 29. The recess 35 has inclined side walls 36. When a specially provided wedge member 37 is inserted into the recess 35, inclined side walls 38 of the wedge member 37 co-operate with the side walls 32 of the recess to force the lid and base parts apart to be a predetermined amount. This facilitates the axial insertion of the optical fibre(s) into the bore 7. The wedge member 37 is adapted to be able to open the lid and base parts selectively in individual clamping sections of the connector, as described above.

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Figure 8 shows a variant of the optical fibre connector shown in Figures 1 to 7. In this embodiment of the invention, the second regions 13 of the bore 7 are arranged to receive ferrules 39 (or other fixing members) crimped (or otherwise fixed) to respective optical fibres 9. The ferrules 39 preferably include protrusions on their exterior, which cut into the connector body in the regions 13 so as to fix the ferrules, and consequently their respective optical fibres, in a specific rotational orientation. The ferrules 39 preferably also axially retain their respective fibres within the connector, to provide resistance to axial pull and/or axial push of the fibres with respect to the connector body.

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The lid and base parts of the connector body (of all embodiments of the invention) preferably are formed from polymer material, e.g. PPS. The resilient clamp member may be formed from the polymer or metal, but metal is generally preferred. Preferred metals include inox steel and beryllium copper. The ferrules preferably are formed from metal, and the plugs preferably are formed from polymer material.

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Figure 9 is a schematic illustration showing three embodiments of alignment means of connectors according to the invention. In Figure 9(a), the alignment means is a bore of the

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connector body, and a longitudinally central main clamping section of the connector body (labelled "Clamp 2") clamps directly onto both of the spliced bare optical fibres, thereby aligning the two fibres with each other. Two other main clamping sections, (labelled "Clamp 1" and "Clamp 3") on each side of the Clamp 2, clamp onto only their respective individual fibres, enabling independent clamping of these fibres. In each of Figures 9(b) and 9(c), there are only two main clamping sections, labelled Clamp 1 and Clamp 3, each of which clamps directly onto a respective one of the bare optical fibres, enabling the independent clamping of the fibres. In addition, in each of these embodiments there is an alignment member located between the two main clamping sections, arranged to align the two fibres with each other. In Figure 9(b), the alignment member is a tube, in particular a glass capillary tube. In Figure 9(c), the alignment member comprises a pair of plates, each of which has an aperture for receiving a respective optical fibre, and a lens (a "micro-lens") arranged to assist in the efficient coupling of light between the fibres. As mentioned earlier in this specification, the plates may be the same as, or similar to, the Figure 13 embodiment of co-pending UK patent application number 0309908.2 filed on 30 April 2003.